Fermentation plant for the co-fermentation of biological wastes and sewage sludge

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1. Introduction

In the past sewage treatment plants were frequently oversized to meet the treatment requirements in the long term. Owing to higher fees and increasing environmental awareness, the actual sewage increase has clearly fallen behind the predicted requirements. Therefore quite a few sewage treatment plants - particularly sludge digestion towers for treating excess sludge - are not used to full capacity today. To increase utilisation, the co-fermentation of sewage sludge with biological wastes has been under consideration for a long time and tested principally in laboratories and semi-industrial plants (Bröker 1991, ANS, 1989). Aside from the remuneration for the treatment of the biological waste, the increase of the methane yield could improve the profitability of the sewage treatment plants.

During co-fermentation the treated biological wastes are mixed with the sludge accumulating in the sewage treatment plant and digested in the sludge digestion towers of the sewage treatment plant. Because the existing infrastructure of the sewage treatment plant can be used, only the reception area and treatment area for the biological wastes must be retrofitted. Due to the increased production of fermentation gas, the gas utilisation capacity might have to be increased. In addition, because a higher contamination can be expected in the centrifuged sludge water accumulating during sludge de-watering, a higher re-contamination of the sewage treatment plant will take place.

The fermentation of biological waste in contrast to sewage sludge has not been used widely up to now. Apparently the complexity of the decomposition process and the need for control accompanied by this as well as the economic constraints have hindered wider use up to now. Biological wastes are still primarily treated in composting plants although anaerobic treatment would be a viable solution for higher water contents in the waste.

2. Co-fermentation of biological waste and sewage sludge

Whereas sewage sludge has passed through a succession of various decomposition processes, biological waste is more or less undecomposed. Consequently, the decomposition degree attainable under anaerobic conditions deviates considerably in sludge and biological waste. Although only a maximum decomposing capacity of 60% has been achievable in sewage sludge up to now, over 90% of the biological waste are decomposable under anaerobic conditions (Schäfer 1998). Compared to biogenic wastes (TS contents up to 50% and higher), sewage sludge (TS 3-7%) is a thin substrate (Engeli et al., 1995). Adding biological waste can therefore increase the TS content without significantly raising the hydraulic load of the sludge digestion tower. Due to the higher percentage of easily decomposable organic substances, distinctly higher yields of fermentation gas are achieved during the decomposition process. Thus Engeli (1995) was able to increase gas formation by 30% by raising the percentage of organic material in the sewage sludge by approx. 20% by adding biogenic wastes. At a ratio of 1:1 between the dry substance of the biological waste and the sewage sludge, Schmelz (1997) reported that accumulation of fermentation gas was tripled. In addition, Schmelz found that the sludge from co-fermentation was easier to de-water, which he attributed to the increased percentage of structures in the biological waste.

Biowertungsgesellschaft Radeburg mbH carries out the co-fermentation of sewage sludge and biological wastes in Radeberg. Tests are currently being conducted to determine which biological wastes are suitable for co-fermentation and in which ratio they can be used to sewage sludge. The result of an excessive concentration of easily utilisable organic material could for example be that the CO_2 content in the digestion gas is sharply increased temporarily and that the block heat and power plant is no longer able to use this gas for energy generation due to the insufficient methane content. In addition, methanogenesis is a very sensitive biological process. Excessive acidification could severely impair the formation of methane. In general it must be ensured that toxic effects as described in the literature e.g. for NH_4 (Behmel et al., 1996) do not occur. Moreover, the quality of the sewage sludge must not be worsened by associated materials in the biological waste because this would raise the price of the utilisation of the sewage sludge.

The target of adding biological waste is to improve the quality of the stabilised sewage sludge, produce utilisable secondary raw material fertiliser and generate regenerative energy.

The excellent usability of biological waste is to be employed for reducing the sewage sludge volume. Thus decomposition degrees during co-fermentation were higher for sewage sludge than during mono-fermentation (Bergmann, 1997). Häfele et al. (1999) reported that the H_2S concentration in the fermentation gas can be lowered and the recontamination of the sewage treatment plant with phosphorus can be reduced by using special co-substrates such as e.g. iron hydroxide sludge from drinking water treatment. In Rosenwinkel's estimation (1998), co-fermentation is ecologically preferable to composting and incineration.

Despite the positive aspects of the co-fermentation of wastes with sewage sludge (or slurry) described above, it can not be categorically assumed that co-fermentation is always the more economical process. Other authors report on negative effects of co-fermentation compared to mono-fermentation. Thus Deckene and Jannsen (1995) recommend mono-fermentation in a single-stage fermentation process for fermenting grease trap contents.

A need for optimisation exists in the process execution of co-fermentation. Up to now, problems have been frequently caused by unstable operating conditions due to an overly frequent change of co-substrates (Rentz, 1997). An increased formation of sedimentary and floating layers can be expected. Therefore thorough intermixing by circulating equipment, a surface scum destroyer and sufficient scum discharging units are required (Kettern, 1997 and Pöpel 1997).

3. Concept of the BVR co-fermentation plant

The starting point of the considerations for planning the BVR co-fermentation plant was the extension of the sewage treatment plant in Radeberg (Obere Röder Special Purpose Association for Waste Water) including plans for erecting an anaerobic sludge stabilising plant in a sludge digestion tower. Another reason was the apparent need for treatment capacities for various types of biological waste at the municipal waste removal company Karl Nehlsen GmbH in Radeberg. During a first step various plant designs for mono- and co-treatment of sewage sludge and biological waste in fermentation and composting plants were investigated. Not only ecological standpoints but also primarily economic aspects were examined. As a result of these investigations, the following sewage sludge and biological waste fermentation concept was developed as the most advantageous concept from ecological and primarily economic standpoints.

The co-fermentation plant was erected during the reconstruction and extension of the sewage treatment plant in Radeberg. Based on the Water Resources Law (in German: WHG) and the Saxon Water Law (in German: SächsWG), the fermentation plant was approved as a part of the sewage treatment plant with an upstream waste treatment plant in the resolution on the official approval of the plan with the extension of the Radeberg sewage treatment plant.

During planning great importance was attached to the flexibility of the fermentation plant. The target was to be able to process as wide a range of wastes as possible. Aside from the liquid and paste-like wastes such as e.g. grease trap contents usually processed in co-fermentation plants, the plant was designed to be able to accept solid biological wastes such as e.g. those which accumulate during the municipal collection of bio-waste containers, extremely soiled biological wastes and industrial wastes such as excess foods, diapers etc. that are not usually processed in fermentation gas plants. The approved acceptance catalogue included over 70 types of waste.

It had to be possible to process biological wastes with and separately from sewage sludge. Therefore the plant was equipped with two fermenters (see Fig. 1) that can also be operated separately. The plant was erected by Linde KCA Dresden and commissioned in the middle of 1999.

A basic flow diagram of the co-fermentation plant is shown in Fig. 2. At the moment approx. 40,000 m^3 of sewage sludge (TS content 5 – 6%) and approx. 15 – 20,000 Mg of biological wastes are processed annually in the plant.

Fig. 1: Overall view of the Radeberg co-fermentation plant

Sewage sludges, liquid and paste-like as well as solid biological wastes are accepted separately in the plant. The pre-concentrated sewage sludge is accepted by the Radeberg sewage treatment plant. Liquid and paste-like wastes can be stored in various, partially heated tanks (optionally over a rack). Solid biological wastes are accepted in a flat bin. An initial rough sorting is carried out in the flat bin. Unsuitable charges can be separated here with the wheel loader and disposed.

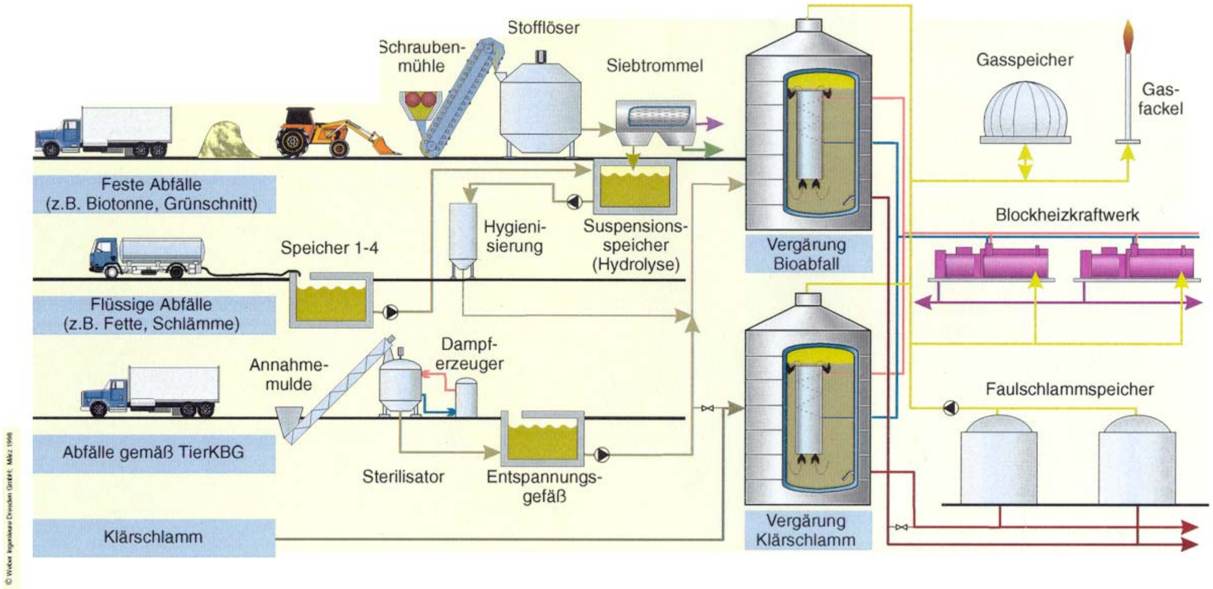

Fig. 2: Simplified basic flow diagram of the BVR co-fermentation plant, Radeberg.
Source: Weber-Ingenieure Dresden

Feste Abfälle (z.B. Biotonne, Grünschnitt)	Solid wastes (e.g. bio-waste container, loppings)
Schraubenmühle	Screw mill
Stofflöser	Pulper
Siebtrommel	Sieve drum
Gasspeicher	Gas tank
Gasfackel	Excess gas burner
Flüssige Abfälle (z.B. Fette, Schlämme)	Liquid wastes (e.g. greases, sludges)
Speicher 1-4	Tanks 1–4
Hygienisierung	Hygienisation
Suspensionsspeicher (Hydrolyse)	Suspension tank (hydrolysis)
Vergärung Bioabfall	Biological waste fermentation
Blockheizkraftwerk	Block heat and power plant
Abfälle gemäß TierKBG	Wastes according to the Animal Carcass Disposal Act
Annahmemulde	Delivery trough
Dampferzeuger	Steam generator
Faulschlammspeicher	Digested sludge tanks
Sterilisator	Sterilizer
Entspannungsgefäß	Expansion vessel
Klärschlamm	Sewage sludge
Vergärung Klärschlamm	Sewage sludge fermentation

The acceptance of wastes according to the Animal Carcass Disposal Act (in German: TierKBG) is conceptually planned but has not yet been realised.

From the flat bin, the wastes are fed into the charging hopper of the shredder with a wheel loader. Then the shredded wastes are transported via ascending belts to Fe-separation and into the pulper. In the pulper waste materials are dissolved and the waste is shredded further.

Stones, bones etc. are removed out of the waste suspension via a heavy medium sewer port. Then the waste suspension reaches a sieve drum with various perforated segments via a weir. Sand and light-density materials are removed out of the suspension here. The waste suspension reaches a mash tank.

The processed wastes are transferred from the tanks via a macerator into the hygienisation tank. Hygienisation is carried out at a grain size < 10 mm at 70°C for over 1 hour.

After hygienisation the biological waste suspension is transferred together with the sewage sludge into the two fermenters. The sewage sludge can be fermented separately from the biological waste as well. This ensures that the biological waste can be marketed as compost in case the costs for sewage sludge utilisation increase sharply. After the material is completely fermented (mesophilic, retention time 15 –20 t), it is de-watered by centrifuging. The centrifuged sludge is cleaned in the Radeberg municipal sewage treatment plant, the solid is re-composted externally and utilised.

The fermentation gas generated during fermentation is converted into electricity by two block heat and power plants. Excess electricity is fed into the mains. The generated heat is used for heating the sludge digestion towers, for hygienisation, for supplying the sewage treatment plant with heat and for heating the service building.

The exhaust air from the treatment plant is captured centrally and cleaned by means of biological filters.

Fig. 3: Shredder with charging hopper

Fig. 4: Pulper for mashing the biological wastes

4. Suitable biological wastes and practical experiences

Aside from the biological wastes usually used in co-fermentation plants such as grease trap contents, laitances, market rubbish etc. (Schmelz, 1997), rubbish that makes high demands on the treatment equipment, as for example rubbish with a very high percentage of disturbing substances, diapers from old people's homes etc., can also be processed in the fermentation gas plant (see Fig. 5). Disturbing substances such as foils, solid plastics, stones, metals and sand can be separated very effectively (see Fig. 6 and 7).

The capacity of the treatment plant can fluctuate considerably depending on the waste used. Thus it was possible to process for example 1.0 – 1.3 Mg of incontinence rubbish with a 12 –15 m^3 water condensate tank in the pulper in one work cycle (batch). The viscosity of the mash did not allow higher metering. It was possible to process 4.5 – 5.5 Mg with a waste mixture of 10 – 20% incontinence rubbish and 80 – 90% biological waste from biological waste containers. Therefore, the specific treatment costs for single types of waste vary greatly.

Fig. 5: Trial shredding of incontinence rubbish from old people's homes.

Fig. 6: Separated fine disturbing substances with a high content of sand.

Fig. 7: Separated rough disturbing substances in the de-watering tank with a high percentage of plastic.

The quantity of metered mash from biological wastes, sewage sludges, and grease trap contents is shown for a period of approx. 1 year in Fig. 8. The mashed biological wastes consist of varying percentages of biological waste from the municipal collection, market rubbish, various production wastes, etc.. The percentage of grease trap contents is extensively constant over the annual line. The quantity of sewage sludges and biological waste mash fluctuates more dramatically.

As shown in Fig. 9, the total quantity of the mash metered in equal parts to the two fermenters fluctuates along the annual line by over 30% between 200 and over 300 m^3/t. The fluctuations of the quantity of waste are attributable on the one hand to seasonal changes of the arisen waste (e.g. in biological wastes from the municipal collection) and to varying quantities of waste acquired on the market on the other hand.

Despite the varying content and composition of the mash to be fermented, the methane concentrations in the fermentation gas range steadily between 60 and 70%. The fermentation gas is well suited for conversion into electricity in the block heat and power plant. Unlike the methane concentration, the fermentation gas production and thus the specific fermentation gas yield per m^3 of metered mash vary considerably. Therefore the optimisation potentials for the operation of the fermentation plant lie in the well directed control of the composition of the mash.

The joint treatment of various biological wastes, grease trap contents, and sewage sludges results in a balanced composition of nutriments. The average P2O5 content in the dry matter is 3.3%. The nitrogen content is 3%. The completely fermented, de-watered sludges are utilised as secondary raw material fertiliser after re-composting with multi-structured material.

The opportunities for the agricultural utilisation of the sludge from co-fermentation depend decisively on the heavy metal content. Tab. 1 shows a comparison between the threshold values of the Sewage Sludge Directive (in German: AbfKlärV), the target values for the agricultural utilisation of sewage sludge striven for within the EU, the average heavy metal contents in the sewage sludge (1997) and the sludge from the Radeberg co-fermentation plant. The comparison shows that the Radeberg sludge has very low contents of heavy metals. On average they are 55% lower than in a sewage sludge with average contamination. Based on the EU target values for 2025, the resulting values fall short of the threshold values by 62 – 96%.

Table 1: Comparison of threshold and target values for agriculturally utilised sewage sludges with the average contents in sewage sludge in general and in the sludge from the Radeberg co-fermentation plant.

	Threshold values of the Sewage Sludge Directive (in German: AbfKlärV) 1992	Target values for the EU threshold value limitation [1]		Average heavy metal content of sewage sludge [2]	Sludge from the Radeberg co-fermentation plant	Shortfall of the EU target values for 2025
		In the medium term (~2015)	In the long term (~2025)	(1997)		
		[mg/kg TS]				[%]
Lead	900	500	200	63	39	80
Cadmium	10	5	2	1.4	0.8	62
Chrome	900	800	600	46	26	96
Copper	800	800	600	274	69	89
Nickel	200	200	100	23	21	79
Mercury	8	5	2	1	0.6	70
Zinc	2500	2000	1500	809	352	77

1) Bergs and Krebsbach, 2000
2) Loll and Melsa, 2001

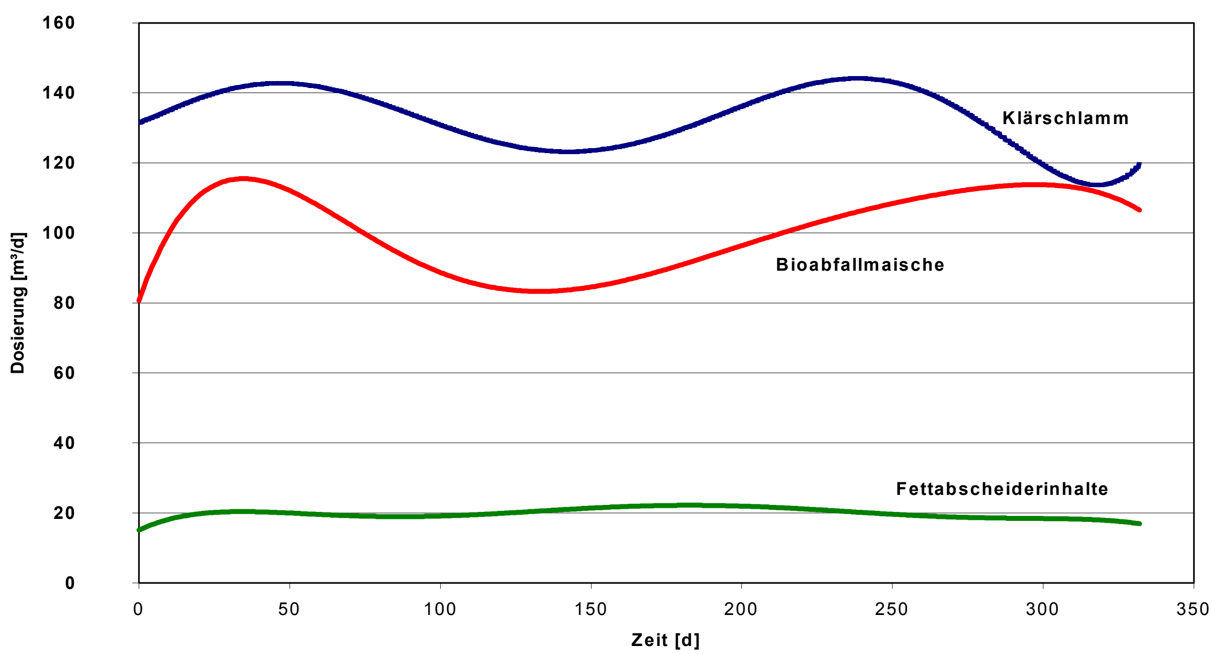

Fig. 8: Used quantity of biological waste mash, grease trap contents and sewage sludges.

Dosierung [m³/d]	Metering [m³/t]
Zeit [d]	Time [t]
Klärschlamm	Sewage sludge
Bioabfallmaische	Biological waste mash
Fettabscheiderinhalte	Grease trap contents

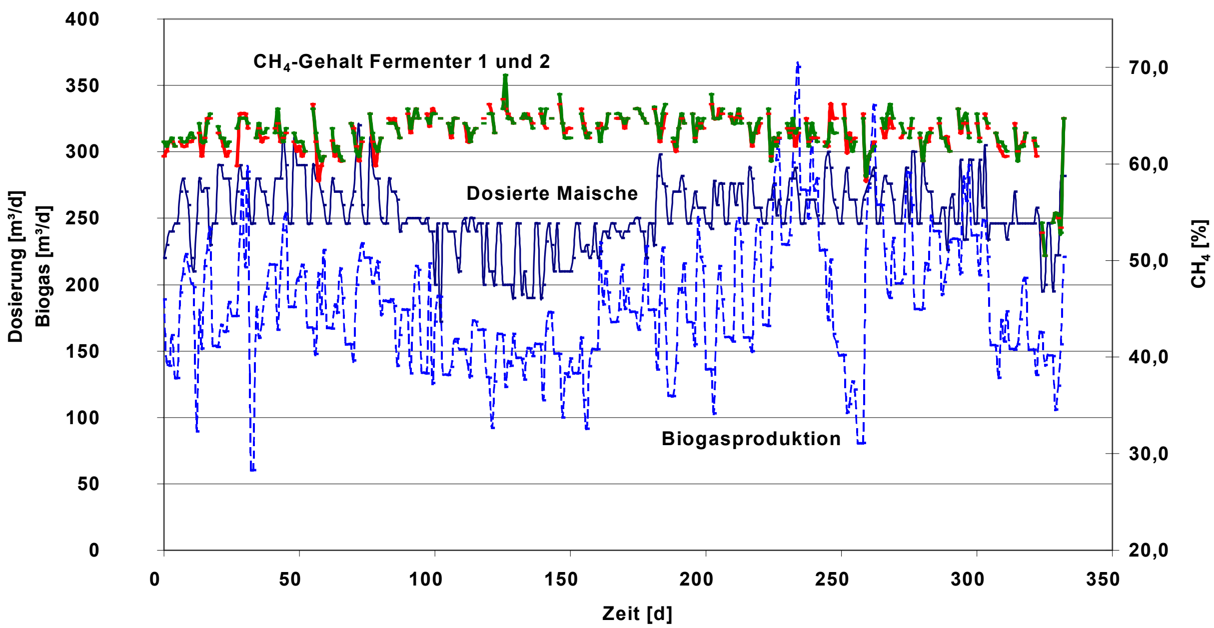

Fig. 9: Biological gas production, methane content in the biological gas of both fermenters (R1 and R2) as well as the used mash (consisting of varying percentages of biological waste mash, sewage sludge, grease trap contents).

Dosierung [m³/d]	Metering [m³/t]
Biogas [m³/d]	Fermentation gas [m³/t]
Zeit [d]	Time [t]
CH_4 [%]	CH_4 [%] 20.0, 30.0, 40.0, 50.0, 60.0, 70.0
CH_4-Gehalt Fermenter 1 und 2	CH_4 content Fermenter 1 and 2
Dosierte Maische	Metered mash
Biogasproduktion	Biological gas production

All in all, it can be concluded that the co-fermentation of biological waste and sewage sludge under the given conditions is technically feasible and economically sensible. The co-fermentation plant guarantees the disposal of the accumulating sewage sludges as well as various biological wastes. By producing regenerative energy the fermentation plant contributes actively to climate protection.

5. Literature

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